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Water Resources
Report 4

Evaluation of the Ground Water Storage Capacity in the Soper Creek Sub-Basin Using the Physical Parametric Approach

OWRC Water Resources Report 4 Barouch GROUND WATER STORAGE, SOPER CREEK 1971

WATER RESOURCES
REPORT 4

Evaluation of the Ground Water Storage Capacity in the Soper Creek Sub-Basin Using the Physical Parametric Approach

By
M. Barouch

ONTARIO WATER RESOURCES COMMISSION
DIVISION OF WATER RESOURCES

TORONTO ONTARIO

1971

PREFACE

In 1965, the Ontario Water Resources Commission initiated studies of water resources and physical conditions in five basins in Southern Ontario, each basin being representative of a type of area common in the province. The collection of the inventory data and the interpretive analyses were designed to provide a better understanding and to facilitate assessment of the occurrence, availability and movement of water for these and similar areas. These hydrologic studies are being undertaken in the River Basin Research Branch and constitute a contribution to the International Hydrological Decade.

This report describes some of the results of hydrogeologic studies being carried out in the southern portion of Soper Creek in the Bowmanville, Soper and Wilmot creeks representative basin.

K Symons

K. E. Symons, Director,
Division of Water Resources.

Toronto,
March 1, 1971.

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ERRATA SHEET

Page	Particulars	Correction needed
vii	Table 2	Caption should include "... materials (Johnson, 1967)"
3	line 2	"acquifer" should read "aquifer"
10	Heading on Figure 2	Should read "Topography and geology of the Soper Creek sub-basin, (Gravenor, 1957)"
11	line 2	"analysis" should read "analyses"
12	Table 1, line 9	"slay" should read "clay"
12	Table 1, Line 10	"candy" should read "sandy"
13	Figure 3	"Well 28" should read "Well 23"
13	Figure 3	should include wells 381 and 18, for locations see Figure 4
21	Table 3, line 5	"clays" should read "clay"
21	Correlation with Particle Size, line 12	"clays" should read "clay" "tills" should read "till"
25	Additional Research, line 2	"furthr" should read "further"
32	Bibliography	Insert, "Gravenor, C.P., 1957, Surficial geology of the Lindsay-Peterborough area, Ontario, Victoria, Peterborough, Durham, and Northumberland Counties, Ontario: Geol. Survey of Canada Memoir 288."
In pocket	Heading on Figure 4	should read, "Generalized fence diagram of the sub-surface geology in the Soper Creek sub-basin, based on composite information from well logs in the vicinity of wells shown on Figure 3."
In pocket	Figure 4 Vertical Scale	"1:132" should read 1" = 132'

FIGURES

TABLES

EVALUATION OF THE GROUND WATER STORAGE CAPACITY IN THE SOPER CREEK SUB-BASIN USING THE PHYSICAL PARAMETRIC APPROACH

INTRODUCTION

This report presents a method to estimate amounts of ground water in storage that may be available for development from basin aquifer systems, using a physical parametric model approach.

Information on storage capacity is required for a quantitative evaluation of a hydrologic balance in any basin where a change in ground-water level is occurring. The storage capacity of the zone of water-level fluctuation must be computed for the period of the hydrologic balance. In addition, information on the storage capacity of an entire basin is needed in connection with planned management of the basin.

In order to develop a physical model, an extensive simplification of the elements of the ground water systems is required. The reliability of such a model is dependent on the validity of the basic geologic and hydrologic data collected, compiled and evaluated as input to the model. The information used in simulating storage capacity is based primarily on available data from the drillers' logs and observation wells.

Descriptions for similar sediments have been found to vary widely among drillers. For reasons of simplification and logical interpretation, the drillers' descriptions of subsurface materials were divided into general classes. Specific yields were assigned to the various classes from results of laboratory studies compiled from published reports, which present specific yields in relation to the texture of the rock or soil. Specific yields were also estimated using particle size analyses and the neutron probe moisture method under field conditions.

In computing the storage capacity, the existing data were used with some assumptions. It was assumed that the value of specific yield was consistent for each aquifer and this was applied as if the aquifer systems were homogeneous.

OBJECTIVE

The objective of this report is to estimate the quantity of ground water stored in all aquifer systems in a basin using specific yields representative of the variety of acquifer materials. The quantity of water evaluated is that stored from a depth of about 10 feet below the land surface to an assumed lower boundary about 20 feet below the surface of the bedrock.

GENERAL DISCUSSION

Methods of Determining Specific Yields

Considerable research has been carried out to determine the specific yields of materials. For the purposes of this study, the best test method reported appears to be that involving volumetric measurement of drainage of water from the materials in the laboratory or in the field. Other volumetric methods include extraction of water from samples using a centrifuge and testing samples against a process plate under a differential air pressure.

Meinzer (1923b) indicated that the quantity of water that will drain from a saturated rock or soil material depends on the length of time the rock or soil is allowed to drain, on the temperature and the mineral composition of the water, both of which affect its surface tension, viscosity, and specific gravity, and on the various physical characteristics of the rock or soil. Not all water contained under saturated conditions can be removed from the rock or soil by drainage. A certain percentage of the water is retained by the molecular and surface tension forces of the solid particles of rock or soil. The water-yielding capacity and water-retaining capacity of rock or soil materials are known as specific yield and specific retention, respectively.

Meinzer (1923a) defined specific yield as the ratio of the volume of water that will drain by gravity from the saturated rock to the total volume of the rock. The specific retention of a rock was defined as the ratio of the volume of water that will be retained against gravity drainage from a saturated rock to the total volume of rock.

The effect of duration of drainage upon specific yield has been noted by many hydrologists. William and Lohman (1949) stated that the true value of specific yield is obtained only after the saturated material has been drained for a long period of time. According to the above authors, the laboratory determination of specific yield of a sand sample was found to be 25 per cent, while a specific yield of 15 per cent was obtained during a pumping test on the same material. The 15 per cent figure obtained may have reached the true value of 25 per cent if the pumping period could have been prolonged.

Prill, Johnson and Morris (1965) presented quantitative information on the phenomena of time of drainage effects on specific yields, as determined by laboratory drainage of a long column of materials. It was concluded that for a sand-size material, a period of two months or more is required for the drainage to reach equilibrium and thus give the maximum specific yield.

Classification of Storage Capacity

The total storage capacity, as referred to in this report, represents the amount of water that would drain by gravity from subsurface aquifers if the regional water level was lowered from an initial depth which represents the average low water level throughout the area during the year to an arbitrary fixed level below the land surface. The demarcation of the lower boundary may depend on one or more of the following factors:

1. General presence of poor quality water below certain depths.
2. General decrease in permeability of aquifers below certain depths.

3. Contamination by upward migration of salt water into overlying fresh water aquifers.
4. The costs to the user of constructing and operating wells from significant depths.

The total storage capacity is given by the equation (Todd, 1967):

$$Wy = Sy\ v$$

where: Wy = is the total storage capacity;
Sy = is the specific yield;
v = is the volume of the deposits.

Basic criteria that should be set up as guidelines with which to evaluate the storage capacity include thickness of the storage units, the vertical and horizontal continuity of the storage units, and their specific yields.

The major storage zones in the Soper Creek sub-basin are composed of drift materials which vary widely in lithologic characteristics from place to place, and only approximate ranges of magnitude of available ground water in storage can be given.

DESCRIPTION OF THE BASIN

As the storage capacity is related to the geologic and hydraulic characteristics of the formations, a brief description of the basin geology is given.

Location, Area and Drainage

The Soper Creek sub-basin is a component of the Bowmanville, Soper and Wilmot creeks representative drainage basin, which is being studied by the Ontario Water Resources Commission under the International Hydrological Decade program. The basin is located in southern Ontario on the north side of Lake Ontario in the County of Durham. The area of the section of the sub-basin is 12.44 square miles or 7,960 acres and is drained by Soper Creek and its tributaries. The location of the study area is illustrated in Figures 1a and 1b.

General Geology

The area is of low relief and has a high percentage of nearly-level land. The major surficial deposits include ice-contact deposits, till deposits, and Lake Iroquois shore, nearshore and lacustrine deposits. The various surficial deposits in the area are illustrated in Figure 2.

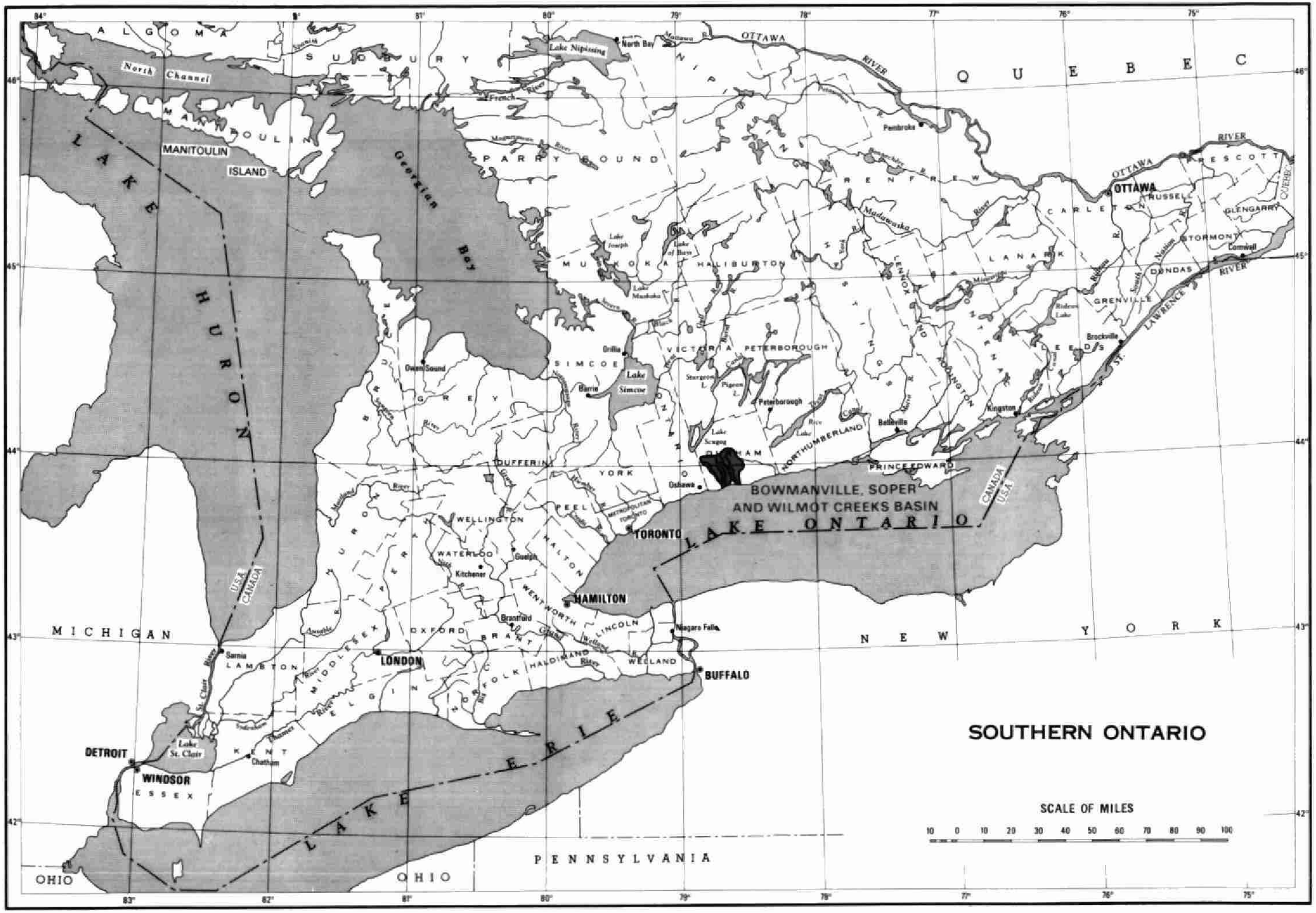

Figure 1a. Location of Bowmanville, Soper and Wilmot creeks in Southern Ontario.

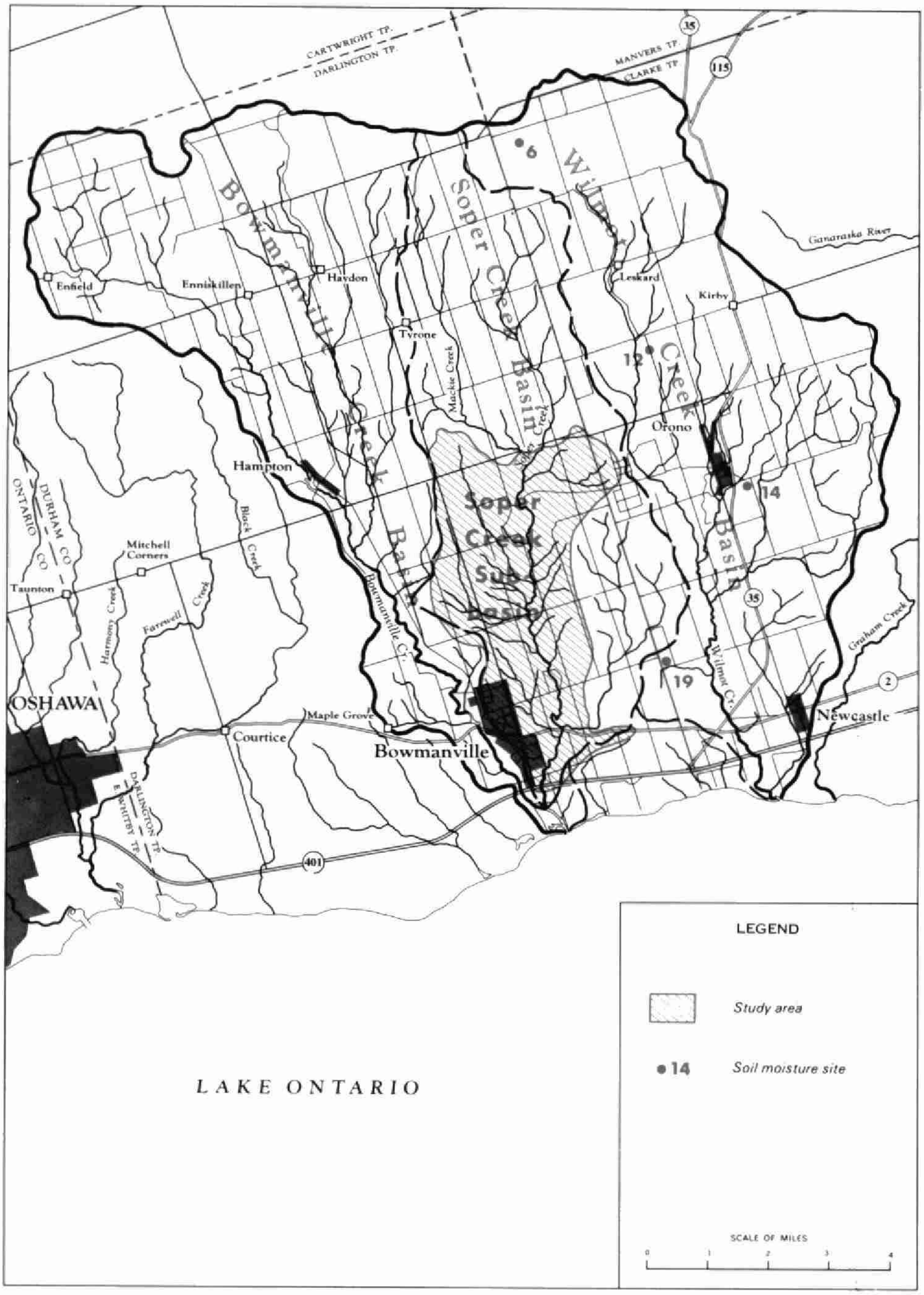

Figure 1b. Location of study area and soil moisture sites.

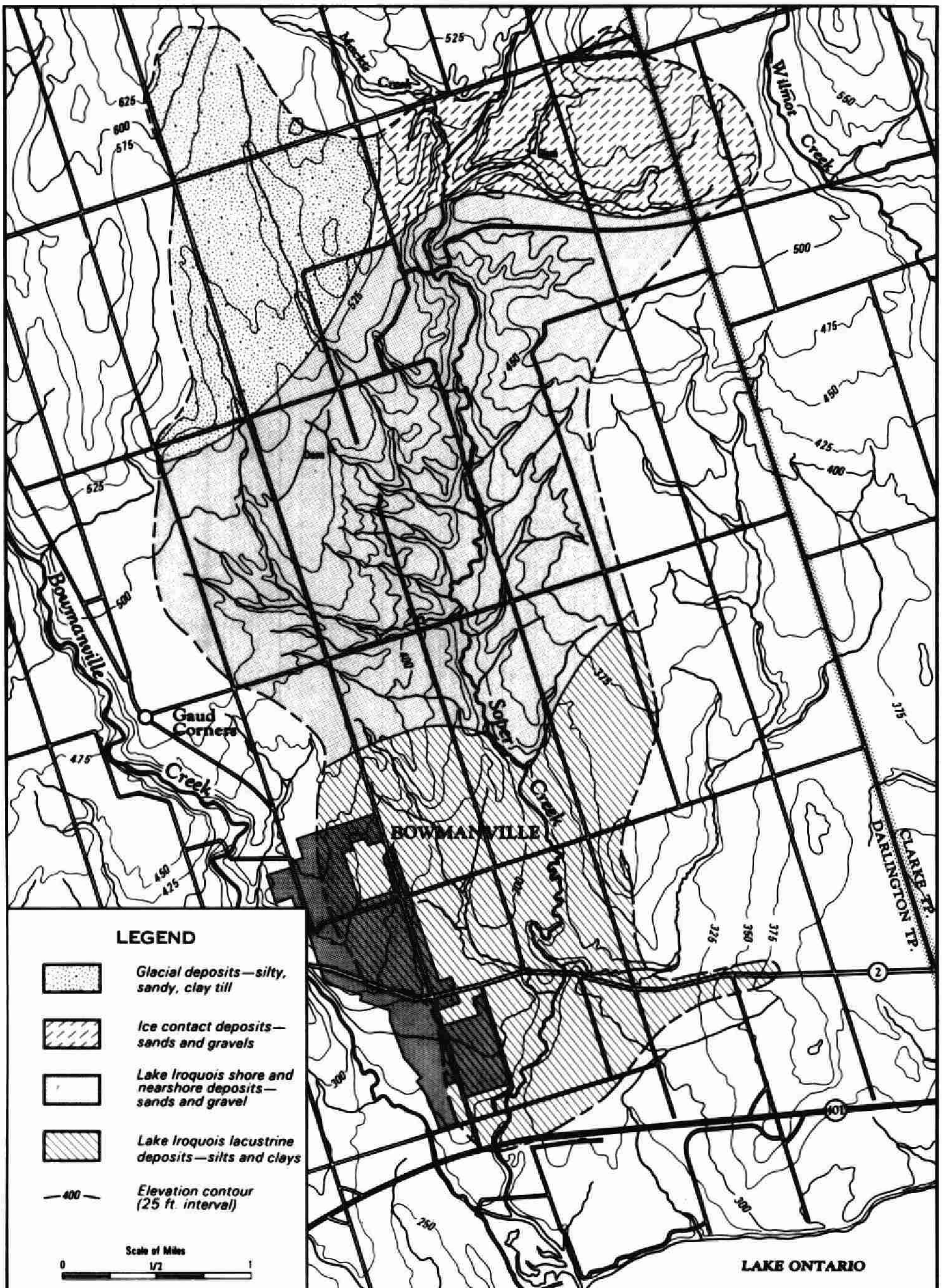

Figure 2. Topography and geology of the Soper Creek sub-basin.

THE PHYSICAL PARAMETRIC MODEL

Basic Steps and Methods

In order to estimate the total storage capacity of the aquifer system, the following steps and methods of analysis were used:

1. Assembly of data from drillers' logs and observation wells and plotting of well locations on a base map.
2. Construction of a fence diagram, based on data from the water-well records and observation wells.
3. Selection of depth zone limits for use in estimating storage capacity.
4. Construction of lithofacies and isopach maps to determine the various storage units within the depth zones selected.
5. Assignment of values of specific yields for the various storage units.
6. Calculation of storage capacity.

These steps of analyses are discussed in detail in the following sections.

Well Logs

The drillers' logs and observation-well data available were assembled and the location of each well was plotted on a base map, as illustrated in Figure 3.

Eight classes of materials to which geologic definitions were given were identified from the drillers' logs. Table 1 shows the drillers' descriptions and the geologic interpretations assigned. The interpretations are based on exposures identified in the field, on the examination of samples taken during drilling of observation wells, and on the locations of wells in relation to the geology of the area.

Fence Diagram

Based on the data from the drillers' logs and observation wells, a fence diagram was constructed, as illustrated in Figure 4. The fence diagram is useful, permitting observations of features that would otherwise be difficult to visualize with a two-dimensional profile.

Selection of Depth Zones

The storage capacity referred to in this report includes the storage capacity within a limited zone having an upper and lower boundary. The upper boundary was fixed at 10 feet below the land surface and represents the average low water level observed in observation wells in the area for water year 1966-1967. An example of an observation-well hydrograph indicating the degree of water-level fluctuations in the basin, is illustrated in Appendix I. The lower boundary was arbitrarily chosen as 20 feet below the surface of the bedrock.

Table 1. Drillers' Descriptions and Geologic Interpretations

Drillers' Definitions	Geologic Interpretation
Sand, dirty sand, sand and gravel	Lake Iroquois sands and gravels
Clay, soil	Lake Iroquois lacustrine silts and clays
Clay and gravel, sandy clay till, clay silt, sandy clay	Upper, brown, silty, sandy clay till
Sand, silty sand, sandy silt	Interstadial sands
Clay and gravel, sandy slay till, clay silt, candy clay	Lower, sandy clay till
Dense clay, compacted clay, clay with pebbles, clay with few stones	Blue clay and basal clay till
Sand, dirty sand at depth	Channel sands
Shale, shaly limestone, limestone	Argillaceous limestone

The selection of the lower boundary at this depth was made in relation to poorer quality water at depth in the bedrock. Water samples taken from about 50 feet below the surface of the bedrock in the St. Mary Cement Quarry near the Town of Bowmanville indicated a total dissolved solids content of about 12,000 ppm.

Lithofacies and Isopach Maps

Based on the fence diagram data and information compiled from the drillers' logs and observation wells, lithofacies and isopach maps were constructed for selected storage units. The storage units considered were:

1. the upper, brown, silty, sandy clay till;
2. the interstadial sands;
3. the lower, sandy clay till;
4. the blue clay and the basal clay till;
5. the channel sands;
6. the bedrock composed of argillaceous limestone.

On the basis of available records in the area near wells 66 and 69 (see Figure 4), the Lake Iroquois sands and gravels were of considerable thickness and extended below the upper fixed boundary of 10 feet. In this area, the Lake Iroquois deposits directly overlie the interstadial sand unit as shown in Figure 4. Because of the approximate lithologic similarity between the two units and the limited areal extent of the Lake Iroquois deposits found below the upper fixed boundary, these deposits were included with the lower unit.

In the other parts of the basin, the kame deposits and the Lake Iroquois sands and gravels and lacustrine silts and clays were thinner and, as such, were located above the upper fixed boundary and for this reason were not included in the study.

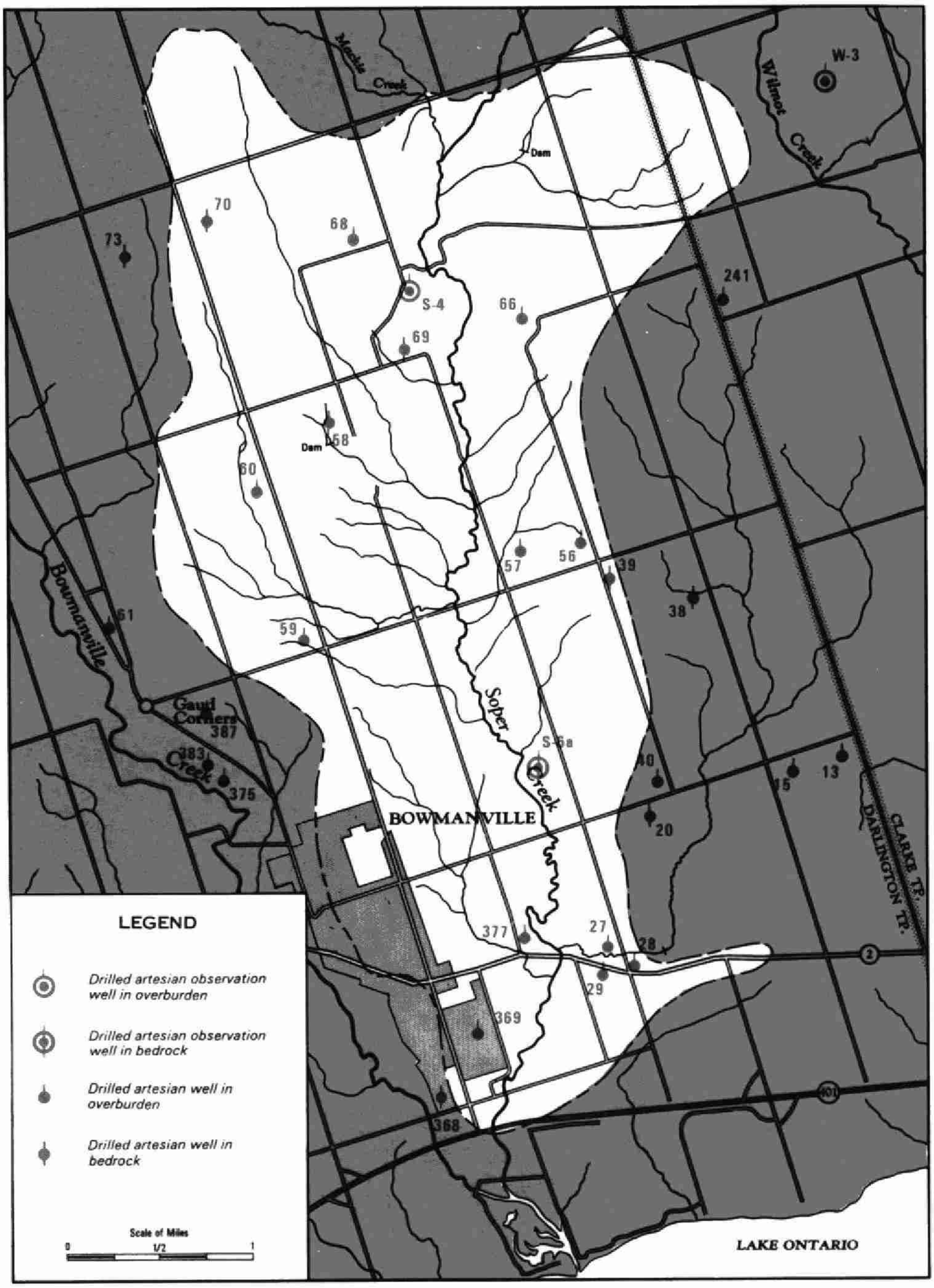

Figure 3. Location of water wells and observation wells in the Soper Creek sub-basin.

Figure 5 shows the upper, silty, sandy clay till unit. The diagram also shows the thickness of the formation and its areal extent. Figure 6 shows the underlying interstadial sands. As discussed earlier, the Lake Iroquois sands and gravels surrounding wells 66 and 69 were incorporated into this unit.

When figures 5 and 6 are used as overlays, the general outline and boundary conditions of the units are apparent and information on hydrologic factors can be derived. For example, a comparatively higher amount of recharge should infiltrate the underlying interstadial sands through the area where the upper, silty, sandy clay till unit is missing, as indicated in Figure 5.

Figure 7 illustrates the lower, sandy clay till unit and the isopach thickness.

Figure 8 illustrates the blue clay and basal clay till unit and the isopach thickness.

Figure 9 shows the sand unit which overlies the bedrock and which is presumed to be a buried channel deposit. The thickness of the channel sand unit varies from 2 to 3 feet. An average thickness of 2 feet was assumed to be representative of this unit.

Assignment of Specific Yields on the Basis of Reported Laboratory Studies

The specific yields derived from water-well records were found to be questionable because of the limited data available from the short pumping-test periods; therefore, it was necessary to assign estimated specific yield values to the general classes of materials on the basis of data compiled from laboratory studies. Table 2 summarizes the specific yields found by various investigators and whose results were used as a basis to evaluate the specific yields of the various materials in the study area.

Table 2. Compilation of Specific Yields for Various Materials (Johnson, 1967)

(All values rounded off to nearest per cent)

Locations	Materials									
	Clay	Sandy Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravelly Sand	Fine Gravel	Medium Gravel	Coarse Gravel
Valley fill, California (Eckis, 1934)	1	10	10	21	31	31	31	27	21	14
Mokelumne area, California (Piper and others, 1939)	4	4	4	26	26	35	35	35	—	—
Santa Ynez River basin, California (Upson and Thomasson, 1951)	2	12	12	12	30	35	35	35	—	—
Sacramento Valley, California (Poland and others, 1949)	3	3	3	10	20	20	20	25	25	25
Smith River plain, California (Back, 1957)	1	5	—	10	15	25	25	25	25	25

Table 2 (cont'd.)

Locations	Materials									
	Clay	Sandy Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravelly Sand	Fine Gravel	Medium Gravel	Coarse Gravel
Ventura County, California (California Water Resources Board, 1956)	—	5	3	25	25	25	21	21	21	21
Santa Margarita Valley, California (California Department of Public Works, 1956)	1	5	10	28	28	28	22	22	22	22
Tia Juana Basin, California (California Water Rights Board, 1957)	1	5	10	25	30	32	28	26	23	18
San Luis Obispo County, California (California Water Resources Board, 1958)	3	5	5	25	25	25	21	21	21	21
San Joaquin Valley, California (Davis and others, 1959)	3	5	5	10	25	25	25	25	25	25
Eureka area, California (Evenson, 1959)	3	10	10	20	20	20	20	25	25	25
Santa Ynez Basin, California (Wilson, 1959)	5	—	5	20	30	30	—	25	25	25
Rechna Doab, Pakistan (Kazmi, 1961)	3	—	5	27	28	23	23	26	26	26
Napa-Sonoma Valleys, California (Kunkel and Upson, 1960)	3	10	5	20	20	20	20	25	25	25
Humboldt River Valley, Nevada (Cohen, 1963)	1	—	19	26	28	27	—	19	—	—
Little Bighorn River Valley, Montana (Moulder and others, 1960)	—	—	17	32	32	32	32	25	25	—
Average Specific Yield	2	6	8	21	25	27	25	25	23	22

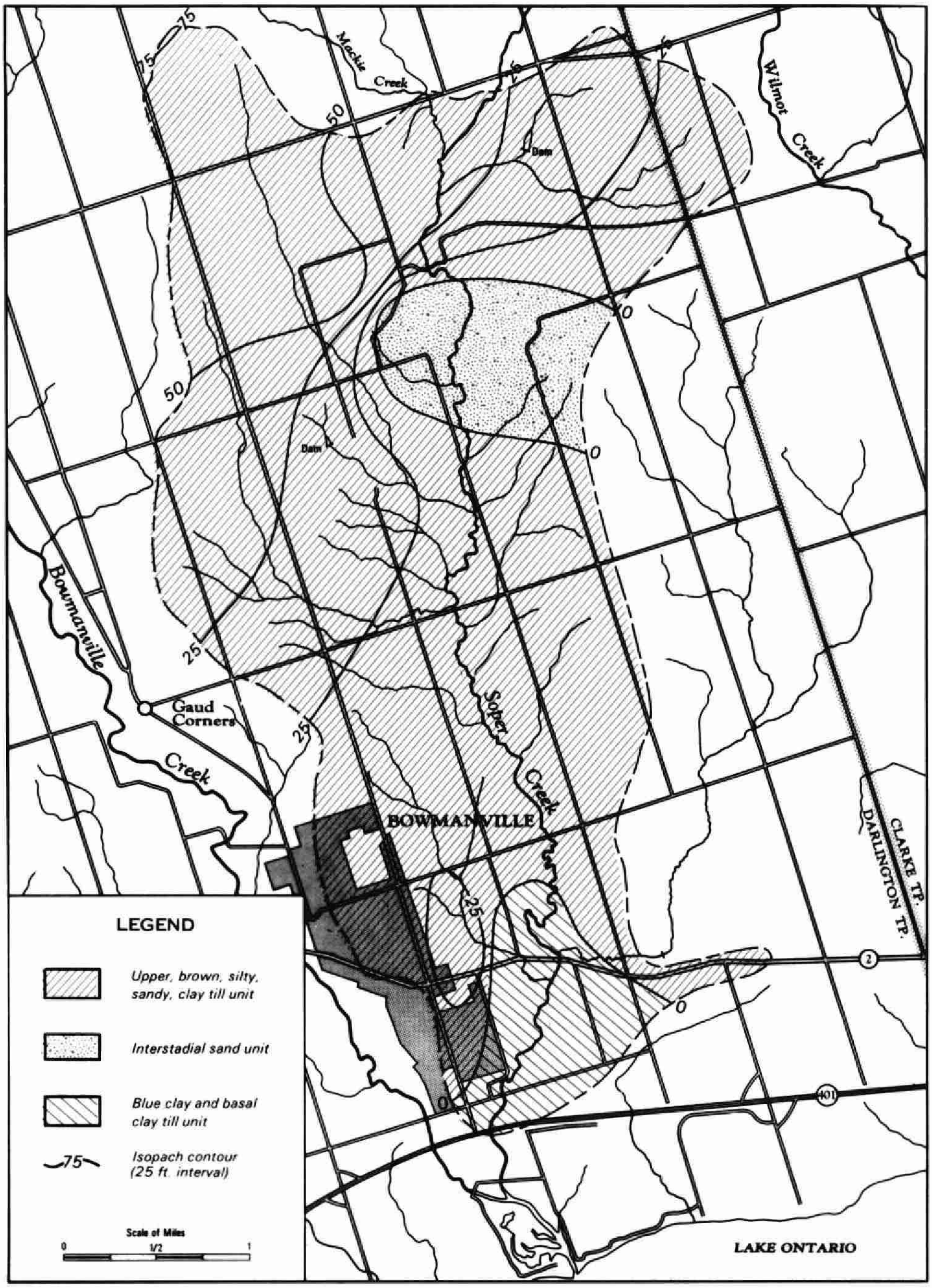

Figure 5. Lithofacies and isopach map showing the upper, brown, silty, sandy clay till unit in the Soper Creek sub-basin.

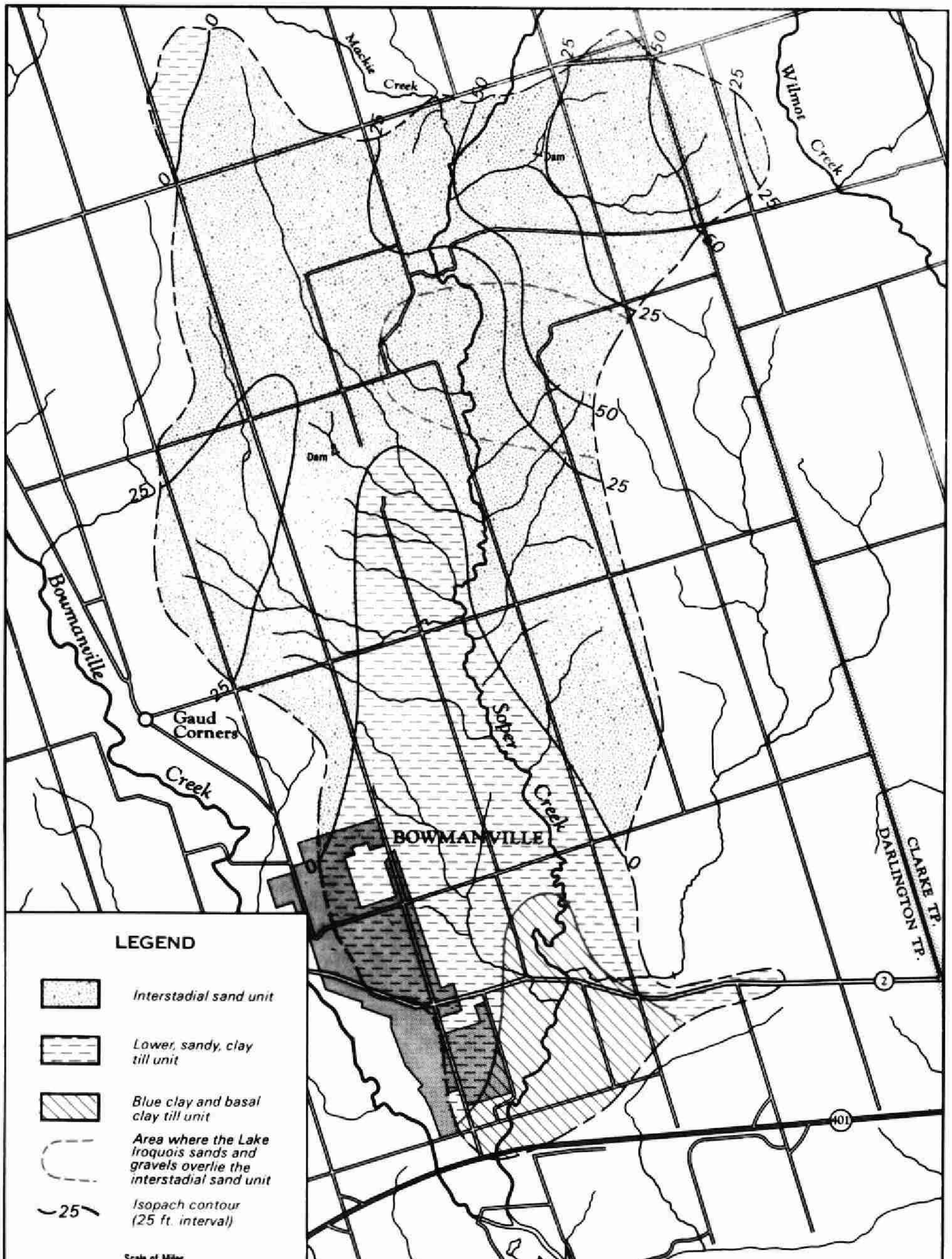

Figure 6. Lithofacies and isopach map showing the interstadial sand unit and Lake Iroquois sands and gravels in the Soper Creek sub-basin.

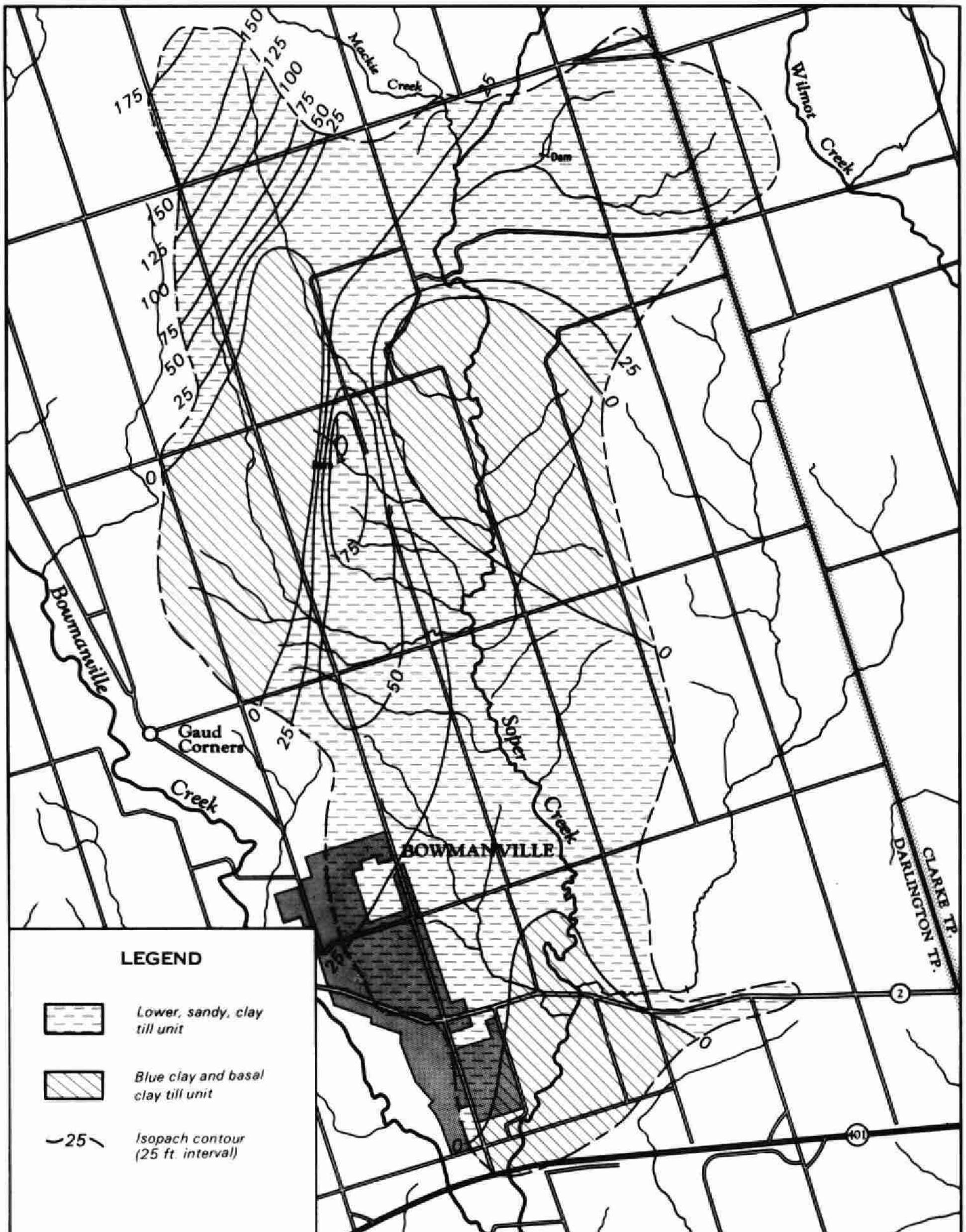

Figure 7. Lithofacies and isopach map showing the lower, sandy clay till unit in the Soper Creek sub-basin.

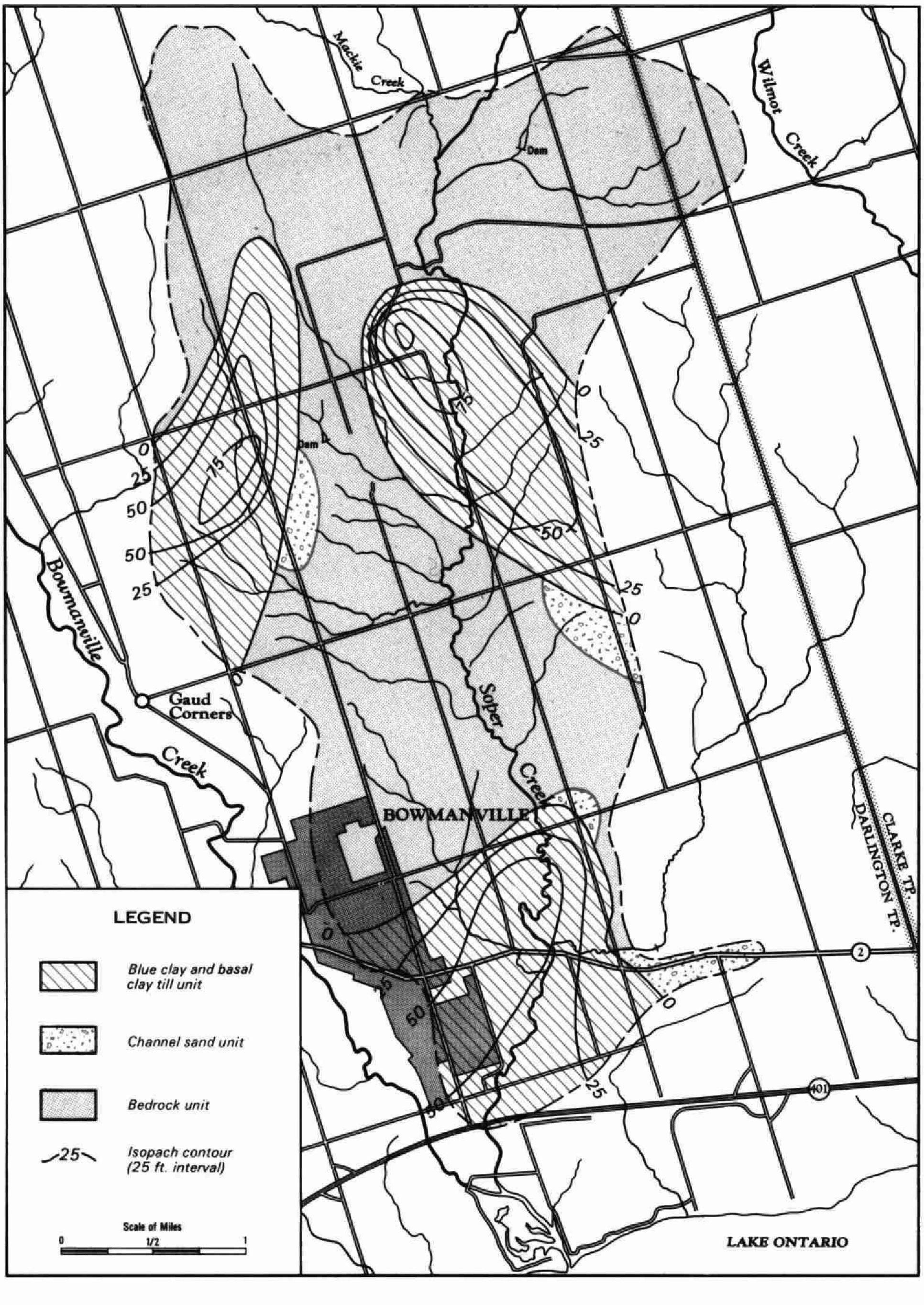

Figure 8. Lithofacies and isopach map showing the blue clay and basal clay till unit in the Soper Creek sub-basin.

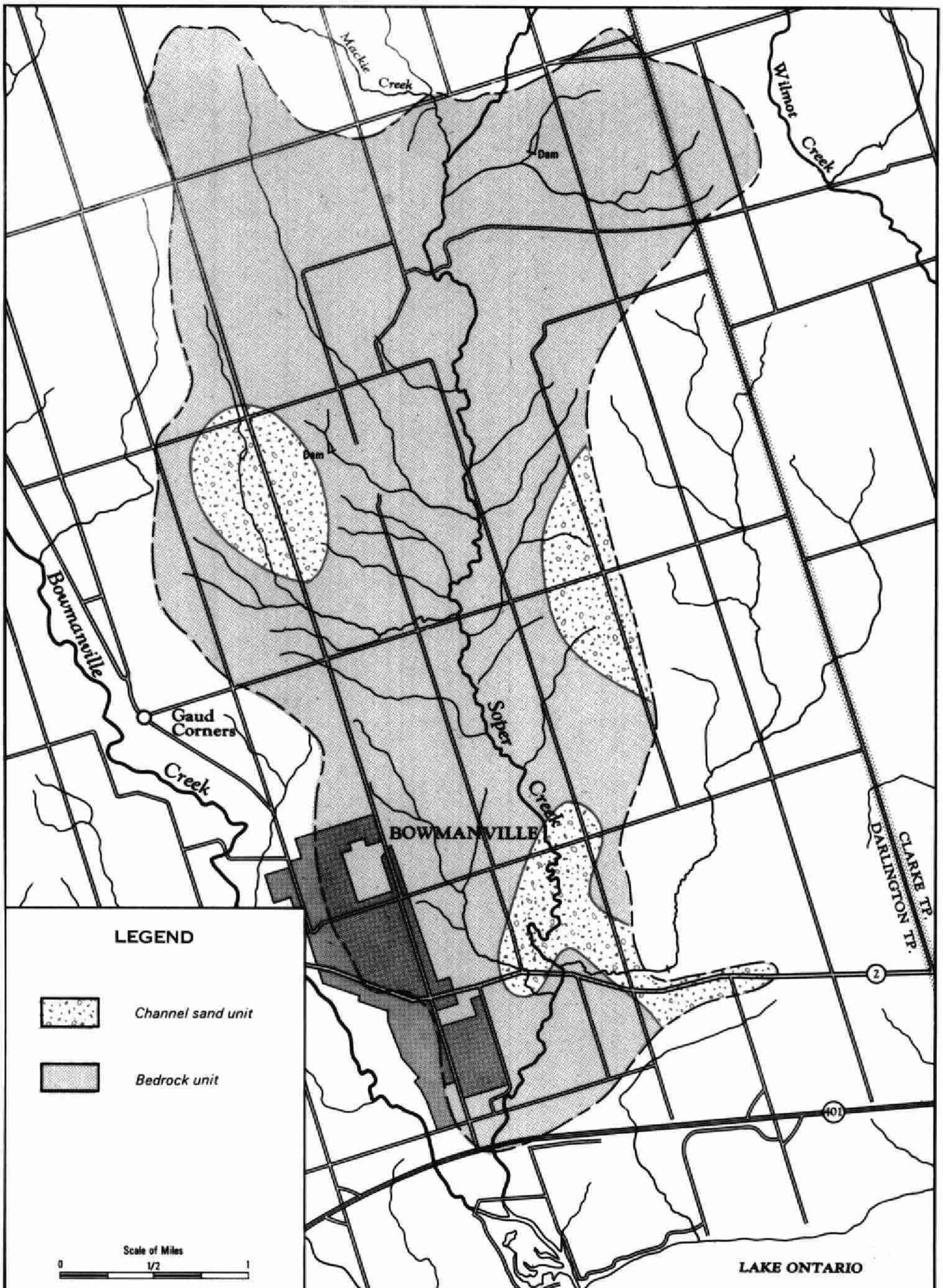

Figure 9. Lithofacies map showing the channel sand unit overlying the bedrock in the Soper Creek sub-basin.

The various specific yields for different materials shown in Table 2 were plotted on a graph, as illustrated in Figure 10, and ranges of specific yields for these materials were delineated. The minimum and maximum specific yields from the graph were then assigned to the various classes of materials, as illustrated in Table 3. Specific yields, ranging from about 2 to 4 per cent, were assumed for the bedrock aquifer.

Table 3. Specific Yields Assigned to the Various Classes of Materials in the Soper Creek Sub-Basin

Materials	Specific Yield Minimum (in per cent)	Specific Yield Maximum (in per cent)
Interstadial sands; Lake Iroquois sands and gravels; channel sands	15	30
Upper, brown, silty, sandy clay till; lower sandy clay till	3	12
Blue clays and basal clay till; argillaceous limestone	2	4

Correlation with Particle Size

As a comparison, specific yields were also determined from particle size analyses using the method developed by Prill and Johnson (unpublished data, 1966). The specific yields were determined by both laboratory and field methods. In their method, specific yields were assigned to materials on the basis of particle size. Lines of equal specific yields were superimposed on a trilinear plot of grain size, as shown in Figure 11.

Disturbed samples taken from some water-bearing formations in observation wells drilled in the basin and samples collected from exposed surficial deposits were analyzed. The results were plotted on the graph in Figure 11. The specific yield of materials grouped under sandy clay till ranged from about 3 per cent to 8 per cent and the specific yields of the material grouped under Lake Iroquois sands and gravels and interstadial sands ranged from about 9 per cent to 35 per cent. No samples were available for analyses of the blue clays and basal clay tills. This method is considered a quick, but approximate way of estimating specific yields. The average specific yields determined by this method and the average specific yields of comparable materials, as determined from Table 3, were of the same order of magnitude.

The Neutron Probe Moisture Method for Estimating Specific Yields under Field Conditions

To test whether or not the specific yields, based on reported laboratory determinations assigned to the various units were within an acceptable range, specific yields were also estimated under field conditions using the neutron probe moisture method.

Some of the subsurface units in the basin are also exposed as surficial deposits in the area and soil moistures determined on these surficial deposits were then related to the same deposits in the subsurface. Using the neutron probe moisture method, the soil moisture was measured in observation tubes which were drilled about 60 inches deep and equipped with

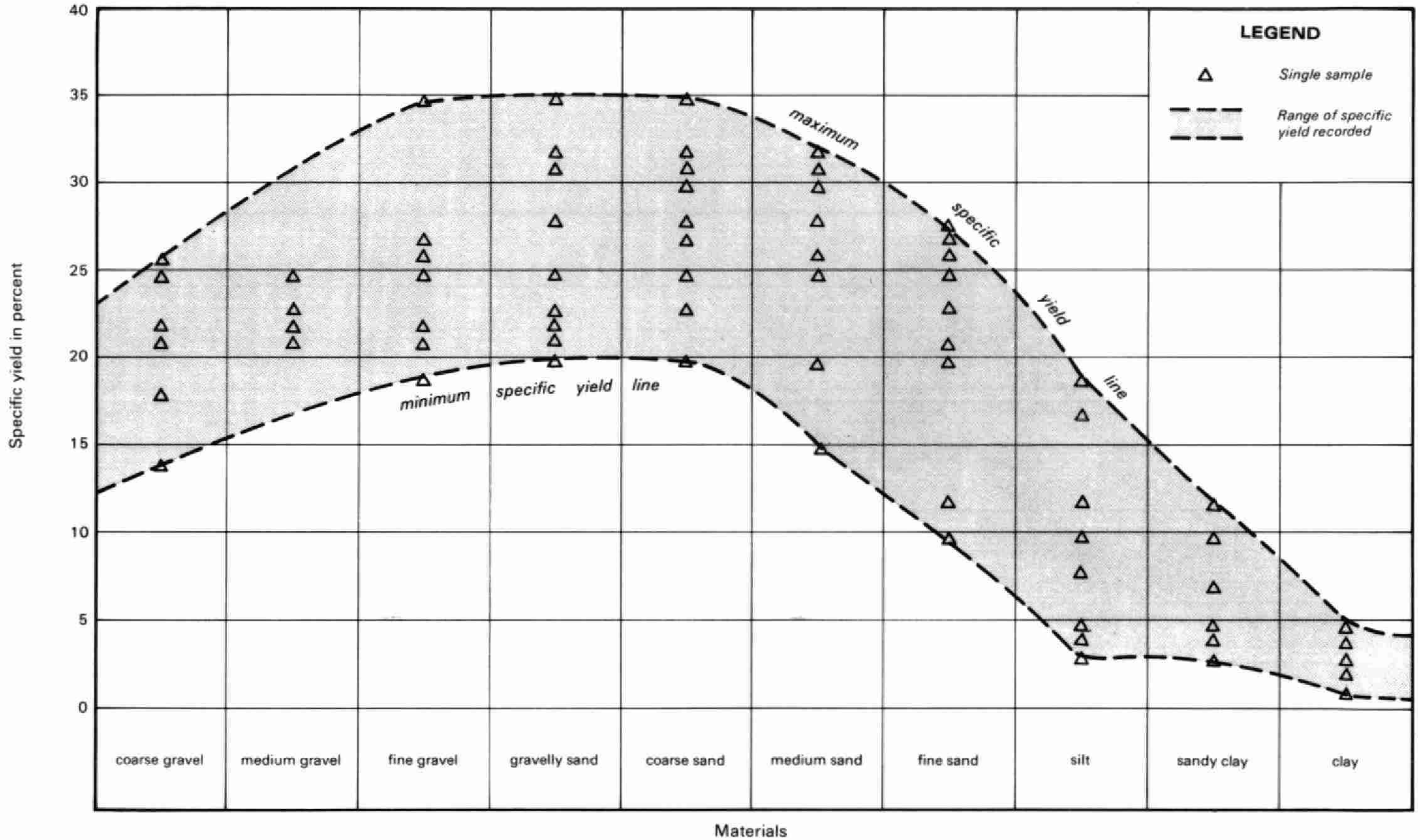

Figure 10. Relationship of specific yield to overburden materials.

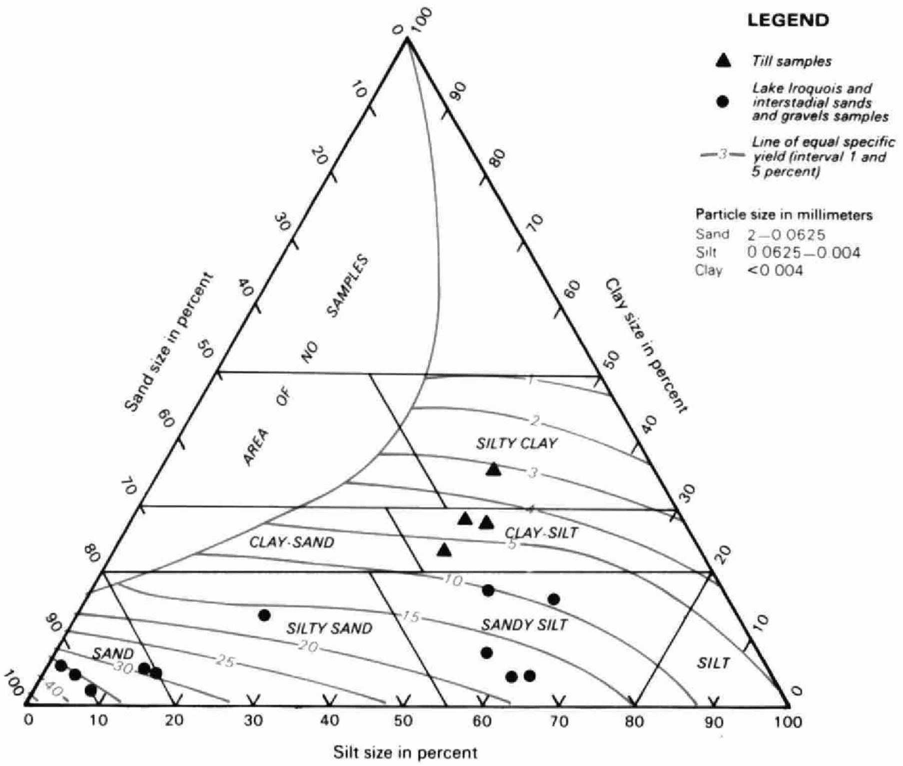

Figure 11. Soil classification triangle showing relationship between particle size and specific yield (after Prill and Johnson, 1966).

aluminum tubing, 1½ inches in diameter. Measurements of soil moisture were taken *in situ* when the material was presumed saturated (after a storm event) and the soil moisture volume was considered to be equivalent to the porosity. After a period of time, the sample was assumed free from any significant amount of infiltrating water and the moisture content was assumed equal to the approximate specific retention. The specific yield was then determined as porosity minus specific retention.

Examples of estimating specific yields using the neutron moisture method under field conditions are given below. The locations where the neutron moisture method was used are shown in Figure 1b. No soil moisture sites are located in the Soper Creek sub-basin; however, information from sites in the Wilmot Creek basin is felt to be representative of conditions in the basin under study.

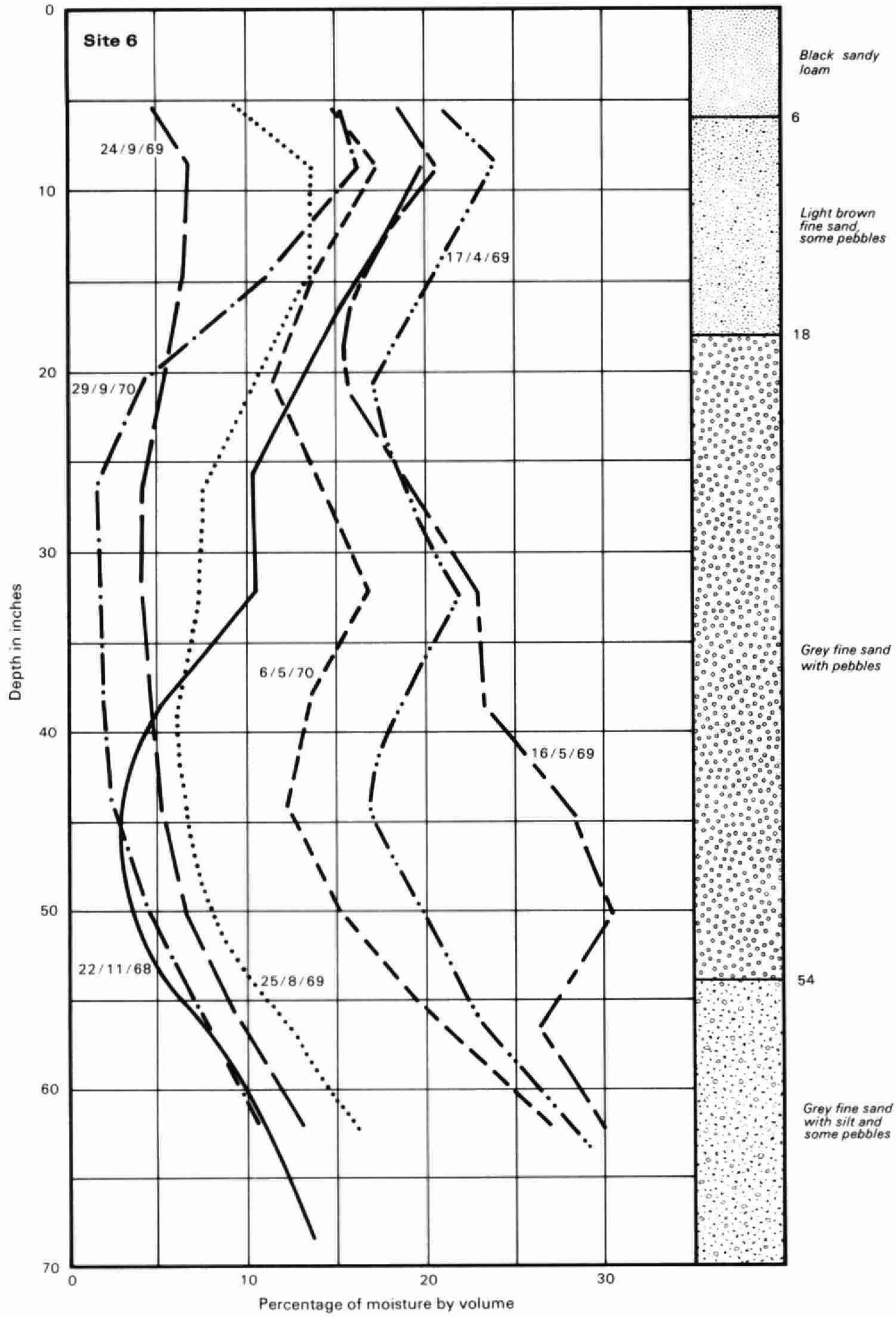

Figure 12. Soil moisture content of fine sand in the Wilmot Creek basin.

As an example, Figure 12 shows the recorded per cent moisture by volume versus depth in inches, measured at different time periods at a station in a fine sand. The figure also illustrates the various formations encountered. In estimating the porosity, it was considered that at a depth of about 50 inches and downward, the moisture content of the formation would not be significantly affected by evaporation. For example, the maximum moisture by volume at 50 inches is about 30 per cent. This was considered to be the approximate porosity for the material at that depth. The minimum recorded percentage of moisture by volume for the material at the same depth is about 4 per cent and is considered to be the approximate specific retention. The specific yield was then calculated as porosity minus specific retention and evaluated as 26 per cent.

In the case of silty, sandy clay, maximum and minimum recorded moisture by volume was 24 and 16.5 per cent, respectively, at 50 inches deep, as illustrated in Figure 13. This gives a specific yield of about 7.5 per cent. These values are felt to be representative of values in the tills in the basin.

The specific yields measured at various locations under field conditions are shown in Figure 14. It was found that the range of specific yields used to estimate storage capacity under laboratory conditions was in the same order of magnitude as that obtained by using the neutron probe moisture method for the sandy formation. In the silty, sandy clay, the specific yield using the neutron probe moisture method ranged from about 4 per cent to 7.5 per cent, compared to 3 per cent to 12 per cent as the minimum and maximum under laboratory conditions.

Additional Research

The neutron probe method was used as an experimental technique to determine specific yields. As a future project to furthr evaluate this method, specific yield values of undisturbed samples tested under laboratory conditions will be compared with results using the neutron probe method.

Computation of Quantities

The area of each storage unit was measured with a planimeter. The area between two isopach lines was also determined and multiplied by the average thickness between the two isopach lines. The volume of each area was then multiplied by the assumed minimum and maximum specific yields. The procedures for this are illustrated by a summary of the computations for each storage unit in appendices II to VII.

The estimation of the total storage capacity was obtained as the sum of the values from each storage unit. The quantities thus derived are listed in Table 4 and amount to a minimum value of 33,000 and a maximum value of 91,000 acre-feet.

The total storage capacity can be compared with the amount of rainfall that normally falls on the sub-basin. Thus, 30.0 inches of precipitation over the sub-basin area of 12.44 square miles amounts to 19,904 acre-feet of water, which means that about 1.6 to 4.6 years of rainfall is stored in the ground water reservoir. This storage is depleted by natural and artificial discharges and replenished by the portion of precipitation that passes through the soil moisture zone to the water-table.

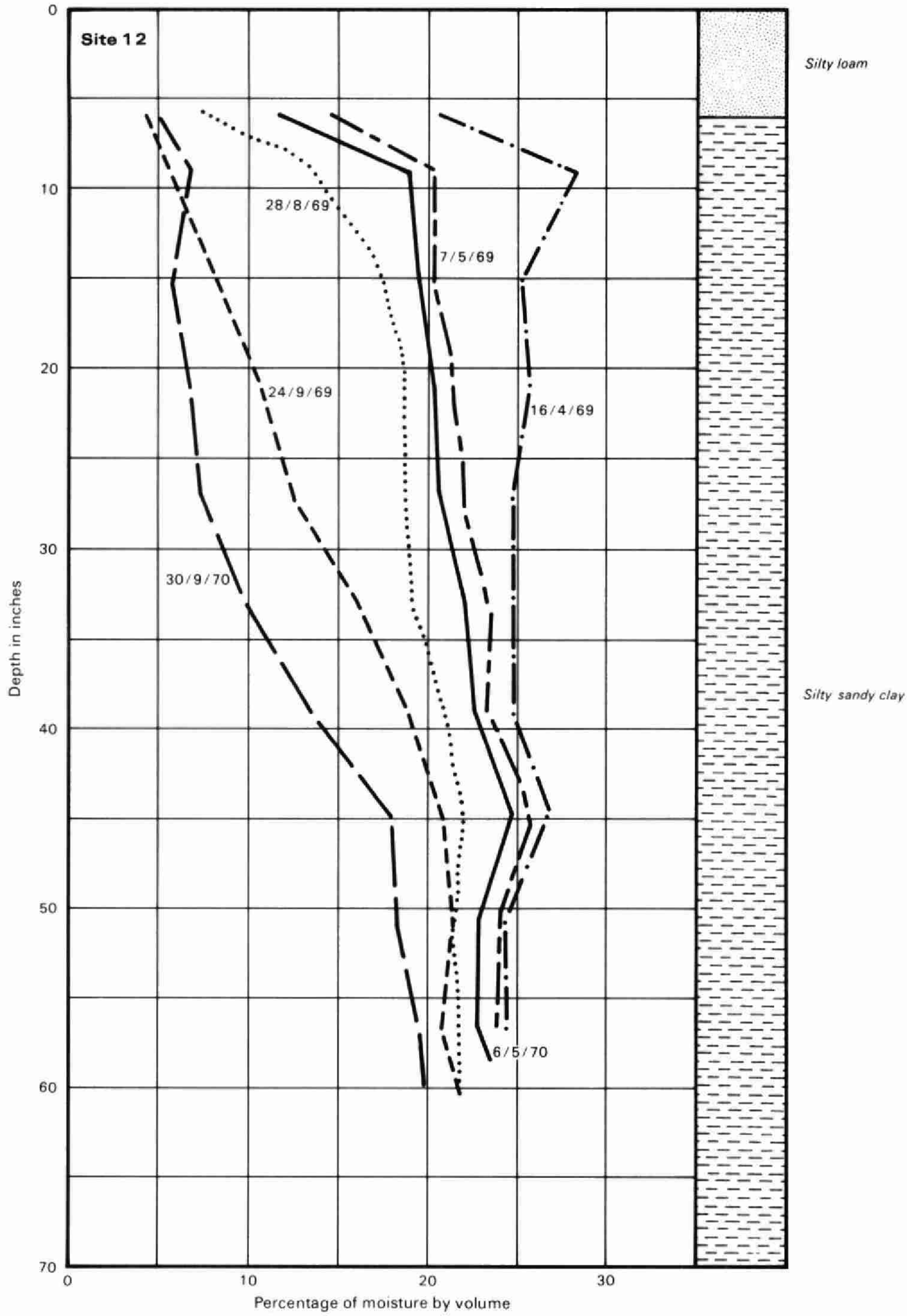

Figure 13. Soil moisture content of silty, sandy clay in the Wilmot Creek basin.

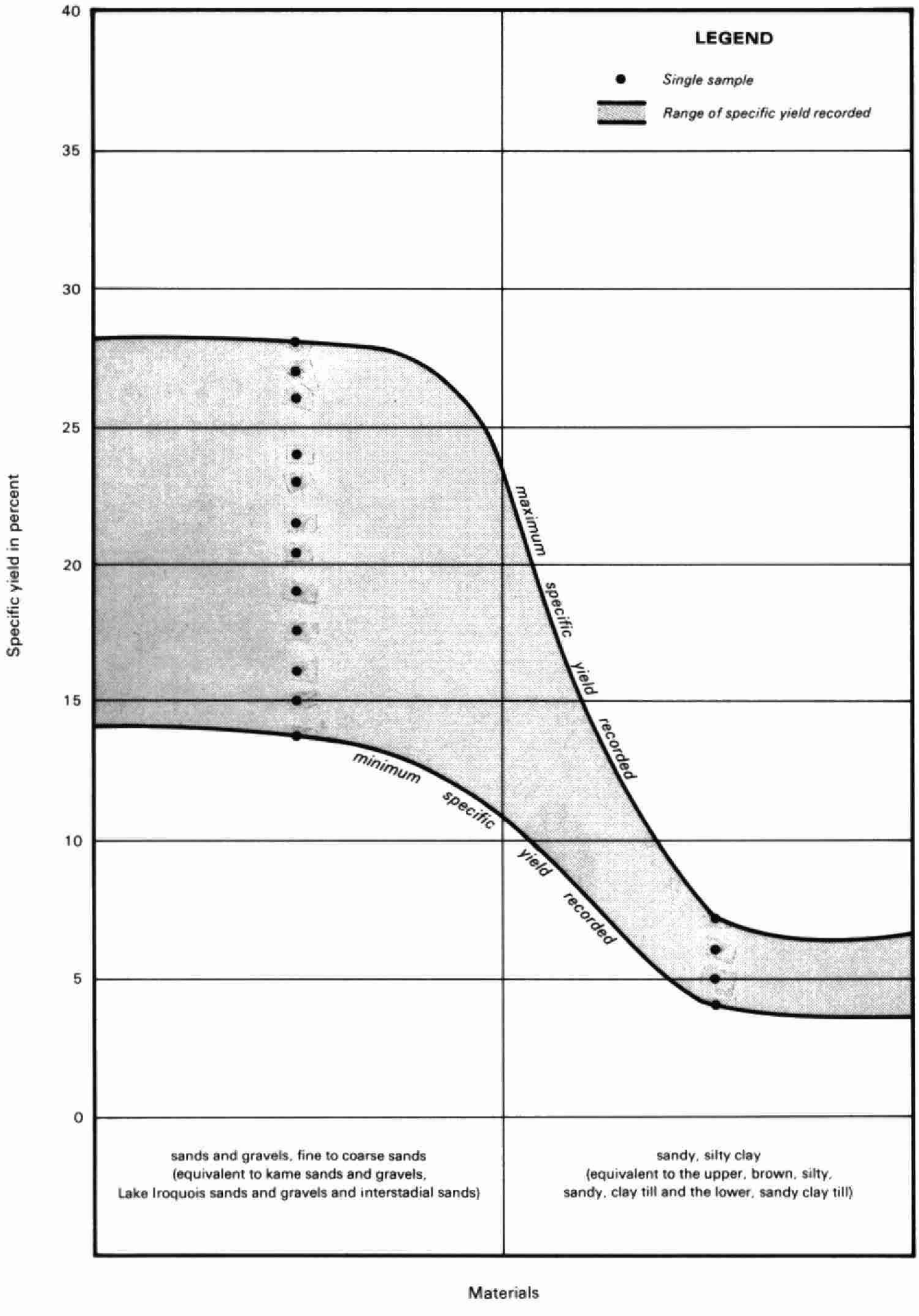

Figure 14. Relationship of specific yield to overburden materials using the neutron probe moisture method under field conditions.

Table 4. Computed Ground-Water Storage Capacity in the Soper Creek Sub-Basin

Storage Unit	Volume (acre-feet)	Minimum Range		Maximum Range	
		Specific Yield in %, using Table 3	Storage Capacity (acre-feet)	Specific Yield in %, using Table 3	Storage Capacity (acre-feet)
Upper silty sandy clay till unit	194,800	3	5,800	12	23,400
Interstadial sand unit	104,500	15	15,700	30	31,300
Lower sandy clay unit	210,400	3	6,300	12	25,300
Blue clay and basal clay till unit	102,700	2	2,100	4	4,100
Channel sand unit	2,200	15	300	30	700
Bedrock unit	159,200	2	3,200	4	6,400
Total Storage Capacity			33,000		91,000
Total Volume	774,000				

ADDITIONAL APPLICATIONS

The combined use of lithofacies and isopach maps is helpful in representing the extent and in determining the characteristics of confined and unconfined aquifers. Lithofacies maps are also useful in determining buried channels in glacial deposits.

In addition, these maps could be used as an aid in establishing water-supply wells. The interstadial sand unit shown on Figure 6 is generally a more favourable source of supply for domestic, stock and other moderate capacity wells. On the other hand, the channel sand unit shown on Figure 9 is too thin to be considered as a major source of water supply.

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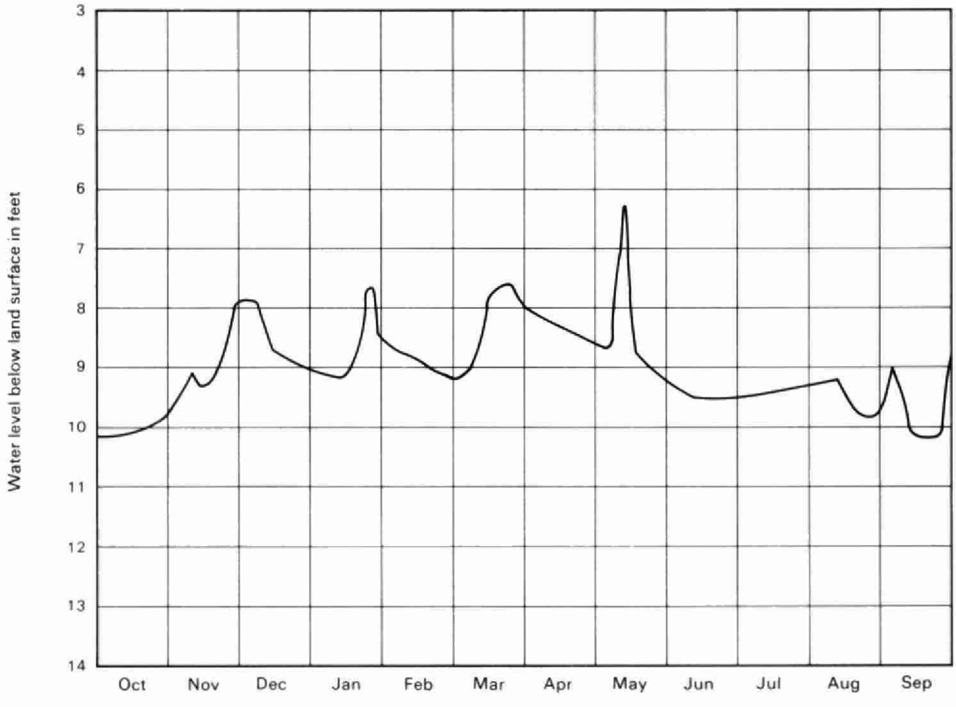
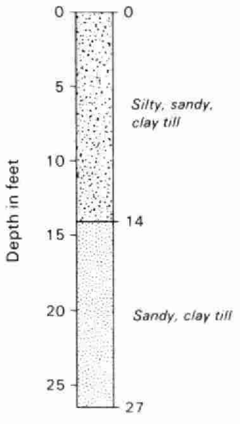
APPENDICES

Appendix I

Hydrograph of Observation Well S-6b Showing Water-Level Fluctuations in the Soper Creek Sub-Basin (Water Year 1966-1967)



Stratigraphic column, observation well S-6b



Appendix II

Estimated Ground-Water Storage Capacity of the Upper, Silty, Sandy, Clay Till Unit in the Soper Creek Sub-Basin

Area (sq. miles)	Area (acres)	Isopach Intervals (feet)	Average Thickness (feet)	Approximate Volume (acre-feet)	Specific Yield (%)		Storage Capacity (acre-feet)	
					Min.	Max.	Min.	Max.
4.81	3,078.40	0-25	12.5	38,500				
0.19	121.60	25	25.0	3,000				
2.00	1,280.00	25	25.0	32,000				
1.72	1,100.80	25-50	37.5	41,300				
2.00	1,280.00	50-75	62.5	80,000				
Total 10.72	8,860.80	—	—	194,800	3	12	5,800	23,400

Appendix III

Estimated Ground-Water Storage Capacity of the Interstadial Sand Unit in the Soper Creek Sub-Basin

Area (sq. miles)	Area (acres)	Isopach Intervals (feet)	Average Thickness (feet)	Approximate Volume (acre-feet)	Specific Yield (%)		Storage Capacity (acre-feet)	
					Min.	Max.	Min.	Max.
5.16	3,302.40	0-25	12.5	41,300				
0.51	326.40	25	25.0	8,200				
2.29	1,465.60	25-50	37.5	55,000				
Total 7.96	5,094.40	—	—	104,500	15	30	15,700	31,300

Appendix IV

Estimated Ground-Water Storage Capacity of the Lower, Sandy Clay Unit in the Soper Creek Sub-Basin

Area (sq. miles)	Area (acres)	Isopach Intervals (feet)	Average Thickness (feet)	Approximate Volume (acre-feet)	Specific Yield (%)		Storage Capacity (acre-feet)	
					Min.	Max.	Min.	Max.
1.10	704.00	0- 25	12.5	8,800				
0.34	217.60	25- 50	37.5	8,200				
0.18	115.20	50- 75	62.5	7,200				
0.13	83.20	75-100	87.5	7,300				
0.12	76.80	100-125	112.5	8,600				
0.14	89.60	125-150	135.5	12,000				
0.35	224.00	150-175	162.5	36,400				
Sub-Total 2.36	1,510.40			88,500				
3.30	2,112.00	0- 25	12.5	26,400				
3.28	2,099.20	25- 50	37.5	78,700				
0.22	140.80	50- 75	62.5	8,800				
0.12	76.80	75-100	87.5	6,700				
0.02	12.80	100	100.0	1,300				
Sub-Total 6.94	4,441.60			121,900				
Total 9.30	5,952.00			210,400	3	12	6,300	25,300

Appendix V

Estimated Ground-Water Storage Capacity of the Blue Clay and Basal Clay Till Unit in the Soper Creek Sub-Basin

Area (sq. miles)	Area (acres)	Isopach Intervals (feet)	Average Thickness (feet)	Approximate Volume (acre-feet)	Specific Yield (%)		Storage Capacity (acre-feet)	
					Min.	Max.	Min.	Max.
0.64	409.60	0- 25	12.5	5,000				
0.41	262.40	25- 50	37.5	9,800				
0.24	153.60	50- 75	62.5	9,600				
0.11	70.40	75	75.0	5,300				
Sub-Total 1.40	896.00			29,700				
0.55	352.00	0- 25	12.5	4,400				
0.33	211.20	25- 50	37.5	7,900				
0.51	326.40	25- 75	62.5	20,400				
0.17	108.80	75-100	87.5	9,500				
0.03	19.20	100	100.0	1,900				
Sub-Total 1.59	1,017.60			44,100				
0.54	345.60	0- 25	12.5	4,300				
0.56	358.40	25- 50	37.5	13,400				
0.35	224.00	50	50.0	11,200				
Sub-Total 1.45	928.00			28,900				
Total 4.44	2,841.60			102,700	2	4	2,100	4,100

Appendix VI

Estimated Ground-Water Storage Capacity of the Channel Sand Unit in the Soper Creek Sub-Basin

Area (sq. miles)	Area (acres)	Isopach Intervals (feet)	Average Thickness (feet)	Approximate Volume (acre-feet)	Specific Yield (%)		Storage Capacity (acre-feet)	
					Min.	Max.	Min.	Max.
1.75	1,120	—	2.0	2,200	15	30	300	700

Appendix VII

Estimated Ground-Water Storage Capacity of the Bedrock Unit in the Soper Creek Sub-Basin

Area (sq. miles)	Area (acres)	Isopach Intervals (feet)	Average Thickness (feet)	Approximate Volume (acre-feet)	Specific Yield (%)		Storage Capacity (acre-feet)	
					Min.	Max.	Min.	Max.
12.44	7,962	—	20.0	159,200	2	4	3,200	6,400

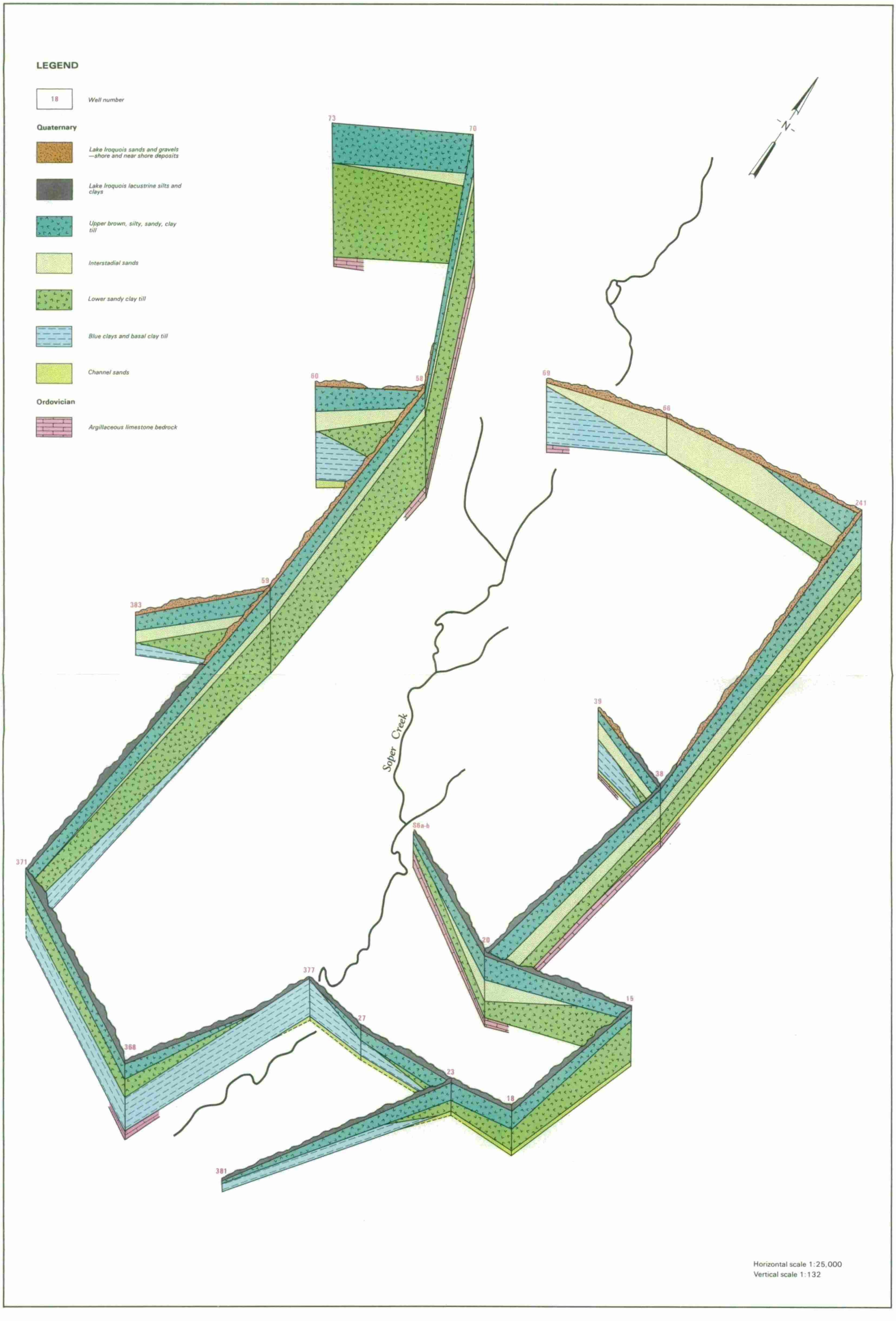


Figure 4. Generalized fence diagram of the sub-surface geology in the Soper Creek sub-basin.